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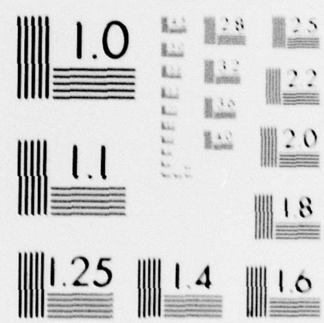
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AERONAUTICAL RESEARCH LABORATORIES

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Structures Technical Memorandum 293

REPORT ON VISIT TO EUROPE IN MAY 1979, COVERING THE 16TH MEETINGS OF THE INTERNATIONAL COMMITTEE ON AERONAUTICAL FATIGUE AND ASSOCIATED VISITS.

G.S. JOST

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(10) G.S. JOST

(12) 26p.

SUMMARY

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CONTENTS

1. INTRODUCTION

The author visited Europe in May and early June 1979 to

(a) attend, as Australian National Delegate, the 16th Meetings of the International Committee on Aeronautical Fatigue (ICAF) held in Brussels, Belgium from 14 May to 18 May 1979, and to present a review of progress in Australian investigations on aeronautical fatigue during the past two years,[1]

(b) present four of the five Australian papers accepted for the Tenth ICAF Symposium on behalf of their ARL authors,[2-5]

(c) visit research centres in Britain, France and Germany for discussions on aeronautical fatigue.

As one of the nominated Australian key persons in the field of aircraft structures in the proposed bilateral Australian-French collaboration, a fourth objective was to

(d) establish contact with our French opposite number.

The visit itinerary is given in Appendix I.

2. REPORT ON THE 1979 ICAF MEETINGS

2.1 Introduction

The 1979 ICAF Meetings were held in the Benelux Room of the Palais des Congres in Brussels, Belgium from Monday 14 May to Friday 18 May, 1979. Australian representation at the Meetings comprised four persons: Mr. C.J. Torkington of the Department of Transport (Airworthiness Branch), Mr. H. Granot of the Commonwealth Aircraft Corporation, Mr. R.H. Stevens of Qantas and the author as Australian ICAF delegate. Total registration at the Meetings was about 180.

Following established practice at ICAF Meetings the Conference, of two days duration, was followed by a three day Symposium. No colloquium was held on this occasion. The Conference comprised the presentation of the National Reviews of each of the eleven ICAF member countries* along with those of Israel and Japan.+ The Symposium comprised

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* Australia, Belgium, Canada, France, Germany, Italy, Netherlands, Sweden, Switzerland, U.K. and U.S.A.

\+ Although not Members, both Israel and Japan have, for some time past, sent representatives to ICAF Meetings and presented National Reviews.

the presentation and discussion of 23 technical papers on the general theme of "Structural Fatigue as a Design Factor".

2.2 16th ICAF Conference (National Reviews)

Reviews of investigations carried out in the field of aeronautical fatigue in the ICAF member countries during the last two year period were presented by the respective National Delegates. In addition, Reviews were presented by representatives of both Israel and Japan. An outline of the main topics dealt with in the various Reviews is given in Appendix II. The Reviews are to be published in a single volume as the Minutes of the 16th ICAF Conference, 1979 by the Belgian hosts during 1980.

2.3 Tenth ICAF Symposium

Twenty three technical papers were presented during the three day Symposium, beginning with the invited Seventh Plantema Memorial Lecture on "Thirty Three Years of Aircraft Fatigue" delivered by its author, Mr. A.J. Troughton of British Aerospace. The Symposium theme of "Structural Fatigue as a Design Factor" was subdivided into three sections: "Airworthiness of Ageing Aircraft", "Fatigue Life Prediction" and "Fatigue Properties in New Technologies". The remarkably high tally of Australian papers accepted for this ICAF Symposium (five) fell into the above categories 1, 3 and 1 respectively. One Australian paper had combined Department of Transport/Ansett Airlines of Australia authorship and was delivered by its DOT author: the remaining four papers from ARL were delivered by this author. Titles and authorship of all Symposium papers are given in Appendix III. The papers themselves are also to be published as a single volume during 1980 as the Proceedings of the 10th ICAF Symposium, 1979.

2.4 Business Meeting

The following items of general interest arose out of the Business Meeting of the National Delegates:

(a) Recent proposed changes in ICAF representation of Italy, the Netherlands, Sweden and Switzerland and that of the General Secretary were formally endorsed. A full listing of, and the addresses of, current ICAF representatives is given in Appendix IV.

(b) Voting on the question of inviting Israel to join ICAF was carried in the affirmative. The General Secretary is now to formally invite Israel's full participation in the ICAF community as its newest and twelfth member.

(c) An offer by Professor J. Schijve of the Delft University of Technology to hold the 1981 ICAF Meetings in the Netherlands had already been made at the opening of the current Meetings. This offer was formally accepted at the Business Meeting, and it is intended that the next ICAF Meetings should take place in Delft during May, 1981.

3. VISITS TO ESTABLISHMENTS IN BRITAIN, FRANCE AND GERMANY

Following the ICAF Meetings, visits were made to establishments in Britain, France and Germany. These comprised the National Engineering Laboratory in Scotland, the Royal Aircraft Establishment (Farnborough) and British Aerospace (Kingston-upon-Thames) in England, Office National d'Etudes et de Recherches Aerospatiales and Establissement Technique Central de l'Armement in France and the Laboratorium fur Betriebsfestigkeit in Germany. For the French visits the author was accompanied by Wg. Cdr. M. McDougal from the Australian Embassy.

3.1 National Engineering Laboratory (NEL)

In the field of fatigue and static strength analysis and testing, the NEL at East Kilbride near Glasgow provides an R and D service to all but the British aircraft industry. (This latter is deemed well able together with the Royal Aircraft Establishment(s) to handle most of its own problems). There has been a spectacular upgrading of facilities for conducting very large scale static and fatigue tests in the last decade or so. Specifically designed loading areas can only be described as vast, and, in view of tests on, e.g. cranes, chains, vehicles and (sections of) off shore oil rigs, as necessary. From one of NEL's public relations brochures: "Components and structures can be tested in static and fatigue machines or on special-purpose test rigs in the new strong-floor Structural Testing Building, where any stress history may be simulated for fatigue and dynamic response testing." Regarding the control and monitoring of individual tests, NEL's policy and practice is to individual, rather than centralised, computers in kiosks located close to each test article. Hydraulic power is generated centrally and piped underfloor to multitudinous outlets.

"Many problems of stress and structural analysis can be solved by finite element methods, for which NEL has a comprehensive suite of computer programs. In particular, they can be used for static analysis, of a structure or component, detailed analysis of local critical regions, dynamic analysis and heat conduction analysis, ... graphical methods of handling input and output data are being developed."

A relatively small effort is underway aimed at solving the problems associated with the manufacture of continuous (standard) glass- and carbon fibre reinforced plastic sections, in particular, of rectangular section hollow beams. Insofar as NEL sees a very bright future for these materials in land transport, a substantial increase in the effort and scope of this development activity is planned.

3.2 British Aerospace (B.Ac.), Kingston-upon-Thames

At this (ex Hawker Siddeley) establishment production and associated static and fatigue substantiation exercises are underway on the Sea Harrier and Hawk trainer aircraft. The design outlook here is very much one of safe life with built-in inspectability; the former typically around 6000 hours (scatter factor 5) and inspection only as and when it might be required. All service Sea Harriers and Hawks in the UK are equipped with electronic versions of RAE fatigue meters and, in addition, some Sea Harriers have solid state airborne recorders for monitoring strain gauge outputs from wing, fuselage and fin stations. Processing of all data is carried out at the central RAF data handling complex in Norfolk.

A full scale fatigue test has been carried out on a single seat Harrier using block programmed loading. Teardown inspection of the test article is now underway. Block programmed loading is also to be used in fatigue testing a double seat Harrier. A full scale flight-by-flight fatigue test on a Hawk using a 25 hour block length comprising 19 sortie types and 57 landings is scheduled to begin in September. In the meantime, fatigue damage accrueing in service aircraft is being monitored by fatigue meter counts and a formula based on Heywood joint S-N data. One fuselage, and one wing fatigue critical location have been identified to date. Component tests are also planned, and wing splice joints have already been tested (under programmed loading) to check the significance of hole mismatch on assembly on subsequent fatigue performance.

3.3 Royal Aircraft Establishment (RAE), Farnborough

Visits were made at the RAE to fatigue groups covering aircraft application, research on metals and composites and the field repair of battle damage.

A large biaxial fatigue rig is being used to generate data, from simulated Concorde fuselage structure, aimed at verifying fracture mechanics crack growth predictions for various combinations of cracked skin and stringer sections. Working sections less than 2m square may be tested, and three jacks in parallel acting along each of two sides allow sufficient flexibility in loading to permit the required strain distributions where needed. Another rig for fatigue testing helicopter

blades from the hub out to midspan, under triaxial loading, is being assembled.

The quick repair of battle damage in the field, so that the aircraft may be flown back to base for more permanent rectification has resulted in impressive glass-and-carbon-fibre cloth and epoxy patching techniques. Typically, a repair of the order of $0.1m^2$ in area can be applied in 10 to 15 minutes and, after a two-hour cure, the aircraft may be flown out. A static strength of up to 95% of the parent metal was quoted for patching on contaminated surfaces, the fatigue strength being of the order of 60%. Battle damage repair kits are being distributed for service evaluation in the RAF.

Seven types of fastener in high and low load transfer joints are being fatigue tested under the FALSTAFF loading sequence. It has been found that fastener detail influences load transfer and hence fatigue performance.

The RAE stress intensity approach to fretting under constant amplitude loading has been widely reported in the literature. Initial work under variable amplitude loading has shown a fatigue performance better than might have been expected for reasons associated with the mechanics of clamping. This work has ceased for the time being, however, because of lack of funding.

The AGARD bolted joint program (involving Britain, the Netherlands, Canada, Belgium, Turkey, France, Italy, Germany and the US) under FALSTAFF loading has indicated that, within sensible limits, hole finish has no significant influence on fatigue life. This finding, which may be understood from residual strength arguments, is not necessarily final: testing so far has been limited, and accompanied by much scatter in results.

3.4 Office National d'Etudes et de Recherches Aerospatiales (ONERA), Paris

The research laboratories of ONERA in the complex visited (Chatillon) employ about 70 engineers out of a total of 120, made up of 40 in each of the Structural Dynamics and Aeroelasticity Groups, 20 in the Fatigue and Fracture Group and the balance in service groups. The visit took the form of a most comprehensive introduction to ONERA and the work of each of the above groups by M. Coupry followed by visits to the various laboratories.

In the Structural Dynamics Group finite element stressing is being used in vibration analyses for situations involving structure to fluid coupling. The response of composite structure to impact, and that of structure surrounded by external fluid to explosive loadings are

being modelled. Attempts are being made to develop optimisation techniques for matching finite element model predictions with experimental data. The response of shell structures (e.g. missiles) to fluctuating pressure fields (acoustic fatigue) is of interest also in terms of the effective functioning of contained equipment. The theory for this problem is developed and reported, but experimental work is being done under contract, and is therefore not available.

The Aeroelasticity Group's work includes aircraft, helicopter and compressor blade problems. For clean aircraft, vibration predictions agree well with practice, but external stores introduce theoretical difficulty. An extension of the doublet lattice method with some hundreds of degrees of freedom works up to a point. Two dimensional transonic, unsteady, inviscid situations can be dealt with, and viscous effects are being introduced. The three dimensional case cannot, however, be handled yet.

Active flutter suppression (AFS) is being achieved via active control technology. An AFS equipped German Phantom has probably already been test flown. The Mirage 2000 may also be AFS equipped if found necessary and/or desirable.

On helicopter blades, which suffer decidedly unsteady aerodynamics, theory has been developed which improves the prediction of blade vibration right up to and into the lower transonic region. The higher transonic region cannot yet be adequately modelled. Predicting the transfer of blade vibration to the fuselage is under development.

Theory to predict the effect of unsteady aerodynamics on vibrating, turning compressor blades is under development. Success, so far, is limited to the case of non-turning blades. The strip method of analysis is being used.

The Group makes use of Randomdec analysis, and has a locally designed mobile laboratory for in-the-field investigations. This is quite self contained, with its own power supply, measurement and analysis capabilities. Outputs from up to 200 sensors can be processed.

In the Fatigue and Fracture Group low cycle fatigue (LCF) has been of prime interest for many years. A predictive technique developed here is now used by SNECMA. The technique, based on a cyclic stress-strain approach and making use of five parameters reputedly yields predicted lives to crack initiation with great precision. Sensitivity to temperature is substantial - a $100^{o}C$ change at $1000^{o}C$ can change fatigue life to crack initiation by a factor of three.

In test on blades, simulation of the measured temperature profile across the critical cross section is achieved by local induction heating. Radial, bending and torsion loadings are applied. Crack initiation invariably occurs (at least for the blades under study) from the trailing edge.

Current effort has shifted more towards problems associated with discs, and with methods for determining more effectively the parameters used in life prediction. Other work of this group includes ambient temperature crack growth in airframes under random loading and crack growth in thick sections, for which a new three dimensional approach has been developed. A composites subgroup is active in mechanical properties and battle damage, the mechanics of fibre/matrix failure (including pullout) and problems associated with the quality control of composite manufacture.

3.5 Establissement Technique Central de l'Armement (ETCA), Paris

ETCA is one of the research laboratories under the Direction des Recherches, Etudes et Techniques (DRET) which is in turn under the Delegation Generale pour l'Armement (DGA). The DGA is the organisation responsible within the French Defence Ministry for the development of all armament* programmes for the French Armed Forces. The reasons for visiting ETCA were to meet M. Bousseau, the nominated French contact in the field of Aircraft Structures in the proposed Australian-French research collaboration, and to gain an understanding of the range of activities undertaken there.

The main laboratories of ETCA at Arcueil employ about 1500, of which about 120 are engineers. The range of subject areas covered includes nuclear protection, measurement techniques, theoretical studies of weapons systems, precision mechanics, metrology and the physics and chemistry of materials. None of the persons present at the round-table meetings nor in the laboratories visited subsequently spoke adequate English: all communication was, therefore, via an excellent interpreter.

The main ETCA departments at Arcueil are:

1) Optics and Physics,
2) Chemistry and Physics of Materials,
3) Technology of Materials, and
4) Structure of Materials.

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* Although in English the word 'armament' has a rather narrow sense, the French 'armement' includes all weapons-carrying vehicles as well as the weapons themselves.

In Group 1) the development of offensive lasers, holography and studies on multiwavelength camouflage, including effects of form and shape are examples of current projects. Typical projects active in Group 2) are development of special purpose organic materials, control and specification of paints for weapons systems and camouflage. Another part of the work of this Group takes place at the French solar oven in the Pyrenees where the behaviour of materials under simulated nuclear flash conditions is studied.

Both Groups 3) and 4) have the introduction of new materials, and their associated problems, as their responsibilities. The paring of component weight to the minimum permissible highlights at least all the usual phenomena exhibited by more commonly used materials. In the metallurgical laboratory studies on materials for springs, armour, ammunition and (light alloys for) extending bridges are underway. Main problems are in the mechanics of cracking and stress corrosion areas. The composites laboratory has work on carbon and Kevlar fibres and applications underway. Quality control and long term behaviour of such materials are seen as major problems. The adhesive bonding of carbon-on-carbon and carbon-on-metal is being followed up. There is also a wear laboratory and one dealing with fracture in new materials.

In the Structure of Materials group investigations range from macro to micro scale. An appropriate array of optical and transmission-and-scanning-electron microscopes (including electron probe) is installed. In the NDI area, the characteristics of eddy current, ultrasonic and acoustic emission techniques are under evaluation. The study of surfaces and special purpose surface treatments, thin films and passive filter treatments against nuclear flash and laser beams are additional current research fields.

In the fracture studies of the Structure of Materials group, crack propagation programmes often make use of 300 to 500 specimens for data collection, and 1000 to establish K_{1C} for all (reasonable) geometric likelihoods. The point here is that French materials specifications, whilst being in many cases similar to those of UK or US materials, are not identical. The French find themselves obliged, therefore, to establish the properties of their new materials themselves. The laboratories contain some 20 older fatigue testing machines, and 20 electro-hydraulic machines ranging from 2 to 200 tonnes in loading capacity and into which may be played sequences typical of low cycle fatigue, random loading or flight-by-flight loading. Much of the representative sequence work derives from the requirements of designing airframe modifications. Specific loading sequences and FALSTAFF and TWIST are being applied to simple open hole laboratory specimens in cumulative damage and crack growth studies: a major effort is underway to try to establish just which predictive rules work best in practice.

Three dimensional cracks are receiving attention on two fronts: the energy method is being used (at ONERA) and the local strain or K around the perimeter of the crack tip using a finite element approach is also being applied.

In the Technology of Materials group the mechanics of fracture is studied. The relationship between fracture toughness and microstructure on light alloys of the 7000, 7050, 7010 series types is being studied. Cast titanium alloys and their improvement represent a major part of the work of this group. Again the relationship between microstructure and fatigue, crack growth and toughness properties is being pursued along with the significance or otherwise of the thickness of K_{1C} specimens. With titanium alloys the determination of K_{1C} is a problem because of the absence of a linear part of the load-displacement record. Automatic crack following equipment is being developed. Many titanium alloy studies are aimed at improving the casting, metallurgical and mechanical properties of cast material. By casting at 900°C and 1000 bars no oxidation occurs, **defect** edges become 'welded' and an almost perfect material results. The largest batch thus cast so far is of about 15 kg. Great hope is held for the future of this work. Other studies on ultra high strength steels and the 7020, 7075 and 7049 series light alloys aim to combine the high static strength of these materials with a much improved fracture toughness.

The Group is also active in very high rate fracture toughness measurement where the precrack is propagated to separation in about 10 microseconds, giving rise to a 10 to 30% reduction in K_{1C}. Welded assemblies for land and naval applications are also tested and modelled using Paris' law, stress intensity and welding line geometry information. This work is aimed at being able to specify inspection intervals for such structure eventually. (Lack of) knowledge of residual stresses in welds is a major obstacle at present. The group is also beginning studies on the mechanics of fracture of composites. One aim is the compilation of a composites fracture 'atlas' containing examples of representative types of failure.

3.6 Laboratorium fur Betriebsfestigkeit (LBF), Darmstadt

A major purpose of this final visit was to obtain an up-to-date account of the present position on the FALSTAFF program. The idea behind this proposal, which has the support of all ICAF, and some other countries, is as follows: by adopting a common, representative, loading sequence for general fatigue testing (called FALSTAFF) and collecting together, all resulting test data, a very comprehensive fatigue data base under a given spectrum would emerge relatively quickly. The LBF was to carry out the collection and collation exercise. It seems that, although the adoption of FALSTAFF has taken place almost universally, the reporting

back to the LBF of data has been honoured only by the Netherlands and Sweden. Consequently the hoped for regular distribution to all interested parties of the consolidated date output has not taken place. The LBF is proposing to try once more to secure cooperation: they propose not to pursue the matter further if their efforts fail to elicit an appropriate response. Another happening which may well have influenced their outlook is a recent 30% cut in Governmental funding. Insofar as this must result in some cuts in expenditure, their possible release from this (continuing) task could be regarded by them as opportune.

A new joint specimen fatigue evaluation program has begun. Precracked 2024 aluminium alloy joints are to be tested to ascertain the most effective techniques for prolonging post-crack fatigue life in service situations. Lufthansa is co-sponsoring this investigation. Another looming future problem is seen to be fatigue in deep offshore oil rigs, where existing depths of the order of 200m are likely to increase by up to five times.

The LBF is cooperating in the British-Netherlands-German helicopter loading spectrum program. Two standard spectra are being developed, one for loads in hinged blades (codenamed HELIX) where maximum bending moments occur around mid-span, and the other for fixed blades (FELIX) where maximum loading is close to the rotor bub. Aluminium and titanium alloy components are to be tested in this program, along with glass fibre reinforced plastic examples. Temperature and humidity effects will be included in the study. Insofar as the German Ministry of Defence supports research work on composites the LBF expects a substantial shift in their work from metals to composites in the very near future. Carbon fibre composites will form the dominating part of this activity.

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1.	Jost, G.S.	A review of Australian investigations on aeronautical fatigue during the period April 1977 to March 1979. ARL Structures Technical Memorandum 303, April 1979.
2.*	Howard, P.J.	The prediction of aircraft life from full scale and component test results.
3.*	Machin, A.S. Mann, J.Y.	The influence of water displacing organic corrosion inhibitors on the fatigue behaviour of bolted joints.
4.*	Baker, A.A. Davis, M.J. Hawkes, G.A.	Repair of fatigue cracked aircraft structures with advanced fibre composites. Residual stress and thermal fatigue studies.
5.*	Jost, G.S.	Fatigue prediction using standardised loading sequence data.

* ARL authored papers presented to the tenth ICAF Symposium, Brussels, May 1979. A copy of the complete Symposium program is given in Appendix III.

APPENDIX I

Overseas Visit - Itinerary and Contacts

Monday 14 May to Friday 18 May	16th ICAF Conference and 9th ICAF Symposium, Brussels, Belgium.
Monday 21 May	National Engineering Laboratory, East Kilbride, Scotland. (Dr. K.J. Marsh).
Wednesday 23 May	British Aerospace, Kingston-upon-Thames, Surrey. (Mr. M.P. Laker).
Thursday 24 May	Royal Aircraft Establishment, Farnborough. (Mr. R.D.J. Maxwell).
Friday 25 May	Institute of Sound and Vibration Research, Southampton. (Prof. B.L. Clarkson).
Monday 28 May	Office National d'Etudes et de Recherches Aerospatiales (ONERA), Chatillon, Paris. (Dr. G. Coupry).
Tuesday 29 May	Establissement Technique Central de l'Armement (ETCA), Arcueil, Paris. (M. Mencarelli).
Thursday 31 May Friday 1 June	Laboratorium fur Betriebsfestigkeit, Darmstadt, Germany. (Dr. J. Franz).

APPENDIX II

National Reviews Presented To The 16th ICAF Conference

The National Review for each ICAF country (and for Israel and Japan) was compiled/edited/arranged by the corresponding National Delegate. As there is no specified presentation format, wide variations in layout and emphasis occur between Reviews.

An attempt has been made in the Table at the end of this Appendix to present, in a loosely classified but compact way, the aeronautical fatigue activity of each country as it has been reported in the National Review. Countries engaged in limited fatigue activity tend to report in great detail, whereas others are forced to condense their material to manageable proportions. This may account for certain omissions: for example, the U.K. Review does not itemise any full scale fatigue testing, yet it is known that the Concorde fatigue test continues.

An additional indication of type and perhaps quality of fatigue activity may be gained from a listing of the organisations contributing to each National Reviews. This is given below

Netherlands	National Aerospace Laboratory (NLR) Delft University of Technology Fokker Aircraft Industries.
United Kingdom	British Aerospace University College, London Institute of Sound and Vibration Research University of Birmingham University of Cambridge National Engineering Laboratory Royal Aircraft Establishment (RAE) National Physical Laboratory
Sweden	Aeronautical Research Institute of Sweden (FFA) The Saab-Scania Company.
Belgium	Review not yet published.
Switzerland	Swiss Federal Aircraft Factory (F+W) Pilatus Flugzengwerke AG

Germany	Laboratorium fur Betriebsfestigkeit (LBF) Deutsche Forschungs-u.Versuchsanstalt fur Luft-und Raumfahrt (DVFLR). Industrieanlagen-Betriebsgesellschaft (IABG) Institute fur Statik und Stahlbau Messerschmitt-Bolkow-Blohm (MBB) Motoren-und Turbinen-Union Ruhr-Universitat Bochum VFW-Fokker.
France	Centre d'Essais Aeronautique de Toulouse (CEAT) Office National d'Etudes et de Recherches Aerospatiales (ONERA) Aerospatiale Laboratoire Central (Suresnes) Avions Marcel Dassault-Breguet Aviation.
Italy	Institute of Aeronautics - University of Pisa Institute of Aircraft Design - Polytechnie of Turin Institute of Aircraft Construction - University of Bologna National Research Council Fiat Research Centre Aeronautica Macchi Aeritalia SIAI Marchetti Aeronautiche Giovanni Agusta.
Australia	Aeronautical Research Laboratories Commonwealth Aircraft Corporation Department of Transport (Airworthiness Branch) Government Aircraft Factories Department of Defence (Air Force Office).
United States	American Society for Testing and Materials (ASTM) NASA Langley Research Centre " Lewis " " Air Force Flight Dynamics Laboratory " " Materials Laboratory

United States (contd.)	U.S. Army Technology Laboratory University of Dayton Research Institute Boeing Commercial Airplane Company Douglas Aircraft Company Lockheed-California Company McDonnell Aircraft Company.
Canada	National Aeronautical Establishment de Havilland Aircraft of Canada Canadair Ltd. Aerospace Engineering and Test Establishment.
Israel	Technion-Israel Institute of Technology Israel Aircraft Industries " Air Force.
Japan	National Aerospace Laboratory Technical Research and Development Institute Fuji Heavy Industries Mitsubishi Heavy Industries Kawasaki " " Aircraft Accident Investigation Commission Civil Transport Development Corporation

Finally, it is noted that a number of collaborative programs are underway between ICAF countries. The nature of the collaboration and the countries involved are listed below.

<u>Standard aircraft loading sequences</u>

TWIST	-	sequence for lower wing root region of transport aircraft (Netherlands, Germany).
FALSTAFF	-	sequence for lower wing root region of fighter aircraft (Netherlands, Germany, Switzerland).
HELIX	-	(mid span) sequence for hinged helicopter blades (Netherlands, Germany, U.K.).
FELIX	-	(root region) sequence for fixed helicopter blades (Netherlands, Germany, U.K.).

Reconstitution of loading sequences

Aim : To devise a method for reconstituting fatigue sequences such that identical fatigue behaviour results from original and reconstituted sequences. (U.K., Australia, U.S., Canada).

AGARD Critically loaded bolt hole program

Aim : To evaluate the effect of hole quality on the subsequent fatigue life of typical joints. (Netherlands, U.K., Germany, France, Italy, U.S., Canada, Belgium, Turkey).

Classification of Current Aeronautical Fatigue Activity in ICAF Member Countries, Israel and Japan, as reported in their 1975-77 ICAF National Reviews

		Netherlands	United Kingdom	Sweden	Belgium*	Switzerland	Germany	France	Italy	Australia	United States	Canada	Israel	Japan
Loading Actions	Gusts	✓	✓				✓			✓				✓
	Aircraft	✓	✓			✓	✓	✓	✓	✓		✓		
	Undercarriages						✓		✓	✓				
	Helicopters	✓	✓				✓		✓	✓	✓			
	Gust Alleviation	✓						✓						
	Load Recorders	✓	✓							✓	✓	✓		
METALS	METALS	METALS	METALS	METALS	METALS	METALS	METALS	METALS	METALS	METALS	METALS			
	Alloys Variability		✓	✓						✓	✓			
	Heat treatment					✓		✓			✓			
	Surface treatment	✓	✓	✓		✓	✓	✓						
Testing Conditions	Environment	✓	✓	✓			✓				✓			
	Thermal fatigue										✓		✓	
	Biaxial "		✓	✓			✓				✓			
	Sequence studies	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓
	Low cycle fatigue						✓	✓			✓		✓	
	Acoustic fatigue		✓						✓		✓			✓
Behaviour Prediction	Cyclic σ-ε studies	✓	✓				✓			✓	✓		✓	
	Crack growth prediction	✓	✓			✓	✓	✓		✓	✓		✓	
	Life prediction	✓	✓			✓	✓			✓	✓		✓	
Component Problems, Studies	Propellers						✓			✓				
	Wheels						✓			✓				
	Lugs	✓	✓	✓						✓				
Joints	Riveted	✓	✓	✓			✓		✓			✓	✓	
	Bolted		✓	✓			✓	✓	✓	✓	✓			
	Hole quality	✓	✓				✓	✓	✓		✓			
	Corrosion inhibitors	✓								✓		✓		
	Analytical Studies		✓	✓										
Fracture Mechanics Studies	Stress Intensity Solutions		✓				✓		✓	✓	✓			
	3D Stress Intensities	✓	✓					✓	✓		✓			
	Crack Growth	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓
	Residual Strength		✓			✓	✓		✓	✓	✓		✓	
	Fracture Toughness		✓			✓	✓	✓	✓	✓	✓			
Full Scale Testing	Aircraft			✓		✓		✓	✓	✓		✓	✓	✓
	Helicopters							✓						✓
Non Destructive Inspection			✓	✓					✓	✓	✓	✓		
Fatigue Life Monitoring								✓	✓	✓	✓		✓	
COMPOSITES	COMPOSITES	COMPOSITES	COMPOSITES	COMPOSITES	COMPOSITES	COMPOSITES								
Specimens, Plates, Bars		✓	✓				✓				✓			✓
Joints			✓	✓			✓		✓					✓
Lugs		✓												✓
Metal/Composite Hybrids, Laminates		✓	✓				✓				✓			
Reinforcement of Cracked/Damaged Structure			✓				✓			✓				
Environmental degradation		✓	✓					✓						
Life Prediction			✓				✓				✓			
Non Destructive Inspection			✓						✓		✓			
Fatigue of Service Structure		✓	✓				✓	✓	✓					
Fatigue Life Monitoring							✓	✓	✓	✓		✓		

* Review not yet published.

10th Symposium : STRUCTURAL FATIGUE AS A DESIGN FACTOR

WEDNESDAY, 16 May '79

09.00 Opening and welcome.

I. 7th PLANTEMA MEMORIAL LECTURE

09.15 A.J. TROUGHTON,
British Aerospace (U.K.).
« 33 Years of Aircraft Fatigue ».

10.00 Discussion.

10.20 Coffee break.

II. AIRWORTHINESS OF AGEING AIRCRAFT

10.40 J. BRANGER (Switzerland).
How to assure safe flying with ageing aircraft.

11.20 L. CRAIG and
U. GORANSON, The Boeing Company, (USA).
Airworthiness assessment of Boeing jet transport structures.

12.30 Lunch.

14.00 C. TORKINGTON, D.O.T. and
G. YOUNG, ANSETT, (Australia).
The role of the airworthiness authority and the airline in the continued operation of older transport aeroplanes.

14.40 D. FINCH, British Airways, (U.K.).
Living with fatigue : the effect on airline operations and engineering of a major and premature aircraft structural fatigue failure.

15.20 Coffee break.

15.40 K. GALDA, Deutsche Lufthansa, and
R. PRINZ, Aircraft and Space Research Laboratory (DFVLR), (Germany).
Mathematical model for the maintenance programme of modern jet aircraft.

16.20 P.H. VAN DER SCHEE, Fokker (Netherlands).
Outerwing lowerskin fatigue testing as a part of the continuing airworthiness programme of the FOKKER F-27.

17.00 Close.

THURSDAY, 17 May '79

09.00 D. WHITE, Vought Corporation, and
T. GRAY, Wright Patterson AFB, (U.S.A.).
Monitoring structural integrity of USAF attack/fighter/trainer aircraft.

09.40 J. DE JONGE, NLR, (Netherlands).
Re-assessment of service life by comparative specimen tests.

10.20 Coffee break.

10.40 M. STONE, and
T. SWIFT, Douglas Aircraft Company (U.S.A.).
Future damage tolerance approach to airworthiness certification.

III. FATIGUE LIFE PREDICTION

11.20 O. BUXBAUM, and
V. GRUBISIC, Laboratorium für Betriebsfestigkeit (Germany).
A method for the optimum design of aircraft wheels.

12.00 Lunch.

14.00 G. JOST, Aeronautical Research Laboratory, (Australia).
Fatigue prediction using standardised loading sequence data.

14.40 P. HOWARD, Aeronautical Research Laboratory, (Australia).
The prediction of aircraft life from full scale and component test results.

15.20 Coffee break.

15.40 J. DARTS, Royal Aircraft Establishment, (U.K.).
Determination of crack growth rates under flight simulation from fracture surface markings.

16.20 H. NOWACK, Aircraft and Space Research Laboratory (DFVLR), (Germany).
Comparison of the actual and the predicted crack initiation life behaviour of notched 2024, 7075 and 7475 specimens under standard loading histories.

17.00 Close.

FRIDAY, 18 May '79

09.00 T. BRUSSAT, Lockheed - California Company, (U.S.A.).
Fatigue crack growth in aircraft joints.

09.40 A. MACHIN, and
J. MANN, Aeronautical Research Laboratory, (Australia).
The influence of water displacing organic corrosion inhibitors on the fatigue behaviour of bolted joints.

10.20 Coffee break.

10.40 W. SCHUTZ, I.A.B.G., (Germany).
Fatigue life under realistic load sequences and corrosion.

11.20 R. ANSTEE, Royal Aircraft Establishment, (U.K.).
Biaxial stress effects in aircraft panel structures.

12.00 Lunch.

IV. FATIGUE PROPERTIES IN NEW TECHNOLOGIES

14.00 J. STURGEON, Royal Aircraft Establishment,
L. BEVAN, Bristol Composite Materials Engineering, and
M. SMITH, Royal Aircraft Establishment (U.K.).
The fatigue performance of carbon fibre composites.

14.40 W. REYNOLDS, A.E.R.E., (U.K.).
Fatigue evaluation in fibre reinforced composite materials.

15.20 Coffee break.

15.40 A. BAKER, M. DAVIS and G. HAWKES
Aeronautical Research Laboratory, (Australia).
Repair of fatigue cracked aircraft structures with advanced fibre composites. Residual stress and thermal fatigue studies.

16.20 G.H. KOCH, Fokker, (Netherlands).
Crack propagation in multiply layer adhesive bonded material.

17.00 Close.

APPENDIX IV

National ICAF Centres - June 1979

General Secretary

Prof. Dr. J. Schijve
Department of Aerospace Engineering, THD
Kluyverweg 1
Delft
The Netherlands

ICAF Centres

The Netherlands	J.B. de Jonge, National Aerospace Laboratory (NLR), Voorsterweg 31 Post Emmeloord
United Kingdom	R.D.J. Maxwell Ministry of Defence (PE) Structures Department Royal Aircraft Establishment (RAE) Farnborough, Hants GU14 6TD
Sweden	Dr. S. Eggwertz The Aeronautical Research Institute of Sweden (FFA) Box 11021 S-161 11 Bromma 11
Belgium	A. Maenhaut Administration de l'Aeronautique Aerodrome de Haren, Hangar 7 B-1130 Brussels
Switzerland	A. Jordi Eidgenossisches Flugzeugwerk (F+W) CH-6032 Emmen
West Germany	Prof. Dr. O. Buxbaum Laboratorium fur Betriebsfestigkeit (LBF) Bartningstrasse 47 D-6100 Darmstadt - Kranichstein
France	D. Deviller Centre D'Essais Aeronautique de Toulouse (CEAT) 23 Avenue Andre Guillaumet 31056 Cedex, Toulouse

Italy	Prof. A. Salvetti Politecnico di Torino, Corso Duca degli Abruzzi 24, Torino
Australia	Dr. G.S. Jost Aeronautical Research Laboratories (ARL) Box 4331 G.P.O. Melbourne 3001, Victoria
U.S.A.	H.F. Hardrath Materials Division, Mail Stop 188 M *NASA Langley Research Center* Hampton, Virginia 23 665
Canada	J.A. Dunsby National Research Council National Aeronautical Establishment Ottawa 7, Ontario KIA OR6

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